ELECTRONIC DESIGN AUTOMATION: INTEGRATING THE DESIGN AND MANUFACTURING FUNCTIONS

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ABSTRACT

As the complexity of electronic systems grows, the traditional design practice, a sequential process, is replaced by concurrent design methodologies. A major advantage of concurrent design is that the feedback from software and manufacturing engineers can be easily incorporated into the design. The implementation of concurrent engineering methodologies is greatly facilitated by employing the latest Electronic Design Automation (EDA) tools. These tools offer integrated simulation of the electrical, mechanical, and manufacturing functions and support virtual prototyping, rapid prototyping, and hardware-software co-design. This report presents recommendations for enhancing the electronic design and manufacturing capabilities and procedures at JSC based on a concurrent design methodology that employs EDA tools.

INTRODUCTION

The continuous increase in complexity of electronic systems is making the design and manufacturing of such systems more challenging than ever before. As a result, designers have been moving from the traditional design approach, a sequential process, to concurrent methodologies where the electronic designer becomes aware of the physical layout process and the manufacturing and assembly issues. This integrated environment improves communications among the various design teams and reduces the rise of multiple time iterations.

With design capacities exceeding a million gates and clock rates of more than 300 MHz, system analysis and verification become the major obstacles in the design phase. This is especially true because of signal integrity problems such as timing delays, level distortions, and noise. Furthermore, as technologies evolve, designers will find it impossible to design efficient systems without the use of sophisticated tools. Since 1989, many companies have been successfully using EDA tools. These tools provide integrated simulation of the electrical, mechanical, and manufacturing functions and lead to a correct by design approach [1-11].

Adopting concurrent design methodologies and employing EDA tools based on processes that support virtual prototyping and hardware-software co-design have proven to reduce cost, decrease time to market, and improve product quality. The rest of this report is organized as follows. First, the benefits of using concurrent engineering and EDA tools are described. Second, industry design and manufacturing practices are summarized. Third, the results of evaluating the design capabilities and procedures at JSC are listed. Finally, recommendations to improve the electronic design and manufacturing functions at JSC are presented.

CONCURRENT DESIGN

Designers have realized that to achieve high productivity the processes used are as important as the tools employed. In recent years, the trend has been a move toward more concurrent design methodologies. A major advantage of concurrent design is that it brings together team members from different disciplines. This results in early detection of design flaws and leads to fewer design changes, a reduction in time to market, and the improvement in overall quality. According to a study cited in [12], concurrent design techniques can reduce product development time by up to 70% and improve quality by up to 600%. Figure 1 shows the relationships between various processes in an integrated design and manufacturing environment that employs concurrent engineering. This environment facilitates hardware-software co-design, virtual prototyping, and rapid prototyping. It also allows for the interaction between electrical, mechanical, and manufacturing engineers.

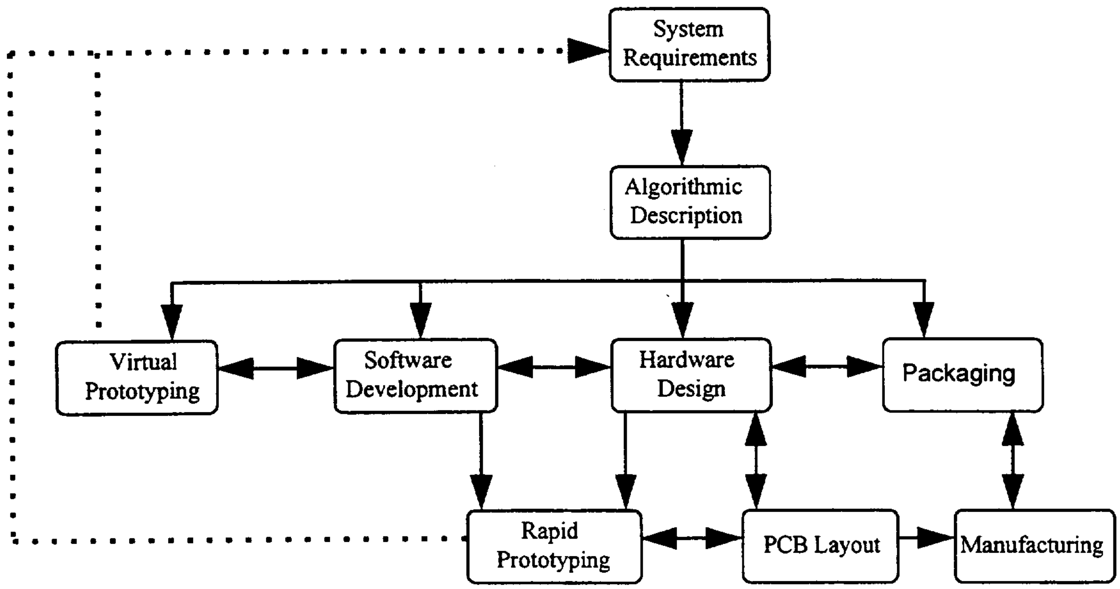

Figure 1.- Integrated Design and Manufacturing Environment

In general, testing hardware and software independently does not lead to complete verification since some problems occur only from the interaction of hardware and software. Delaying integration until the hardware design is complete may impact the cost and time schedule. In addition, if testing is delayed until the board is manufactured, the pressure will be on the software developer to resolve the problems. Concurrent design supports hardware-software co-design and allows for interaction between software and hardware engineers. In this environment, problems can be diagnosed and corrected at the earliest possible phase of the design cycle when the software and hardware engineers can coordinate their efforts so that problems are fixed either in hardware or software depending on the best solution.

While hardware prototyping may still be necessary at some point in the development cycle, taking full advantage of software simulation can significantly improve the overall process. A relatively new technique, virtual prototyping, is used to graphically simulate the operation of a system using a model that best matches reality. In addition to detecting design flaws, virtual prototyping guarantees that the system's operation and performance meet the initial system requirements. Although this approach leads to an increase in the time invested at the beginning of the design process, it reduces the time required for software and hardware integration.

Another important feature of concurrent design is that it facilitates Rapid Prototyping (RP). RP is best achieved by working at a high level of design automation using Hardware Description Languages (HDLs). HDLs take the hardware architecture description and automatically translate it into a physical implementation using various devices such as Application Specific Integrated Circuits (ASICs), programmable logic devices (PLDs), custom Integrated Circuits (ICs), and Field Programmable Gate Arrays (FPGAs). Gate arrays are used for fast turn around prototyping when the design requires better performance than can be achieved with PLDs. Custom ICs can be optimized for performance and functionality but they are time consuming and costly for normal prototyping. While the advantages are many, according to [4] less than 20 percent of the electronic designers in the US have adopted HDLs for RP.

ELECTRONIC DESIGN AUTOMATION

EDA tools provide an effective environment to integrate the design and manufacturing processes. A state of the art EDA system is able to:

- Perform electrical, mechanical, and manufacturing simulation.
- Analyze various design levels, from IC to complete systems.
- Perform mixed-signal (analog and digital) simulation.
- Perform high-level synthesis (behavioral and HDL).
- Support hardware-software co-design, virtual prototyping, and rapid prototyping.
- Provide a centralized database of files accessed by all software modules.
- Offer simultaneous access to all teams.
- Automate data exchanges and provide a standard format for information to be communicated both within the organization and with customers and vendors.

Some EDA companies such as Cadence, Mentor Graphics, Synopsys, and Viewlogic, offer a wide range of software tools that support most of the design functions listed above. The user, however, must recognize that each step of the design process has its own specialized set of tools. Therefore, an organization must carefully determine its design needs and identify those tools that satisfy them. The elements of an EDA system may be grouped as follows:

- Entry tools (Include schematic capture, block diagram and state diagram entry tools, and hardware description language editors).
- Simulation tools (Include analog and digital simulators, timing simulators, HDL simulators, and signal integrity analysis, electromagnetic interference, thermal, vibration, and fatigue analysis, and faults analysis).
- Synthesis tools (Include HDL entry and simulation and behavioral languages).
- PCB tools (Include layout editors, routing tools, and design rule checkers).

INDUSTRY DESIGN AND MANUFACTURING PRACTICES

EDA tools have been successfully used by many companies representing a wide range of industries including automotive, communications, semi-conductors, aerospace, and computers. A review of articles reporting the results of using EDA tools by more than 23 different companies revealed that in addition to handling complex designs, the use of EDA tools reduces development time by up to 75%, decreases cost by up to 50%, and improves product quality significantly.

In spite of the many advantages of EDA tools, it is estimated that only 35% of all designers use them. Furthermore, a 1996 survey by Integrated System Design Magazine [13], completed by 140 EDA users, revealed that not all users take full advantage of the capabilities of EDA tools. The results of the survey are shown in Figure 2. As can be seen in the Figure, schematic entry is still used in twice as many design groups as HDL entry.

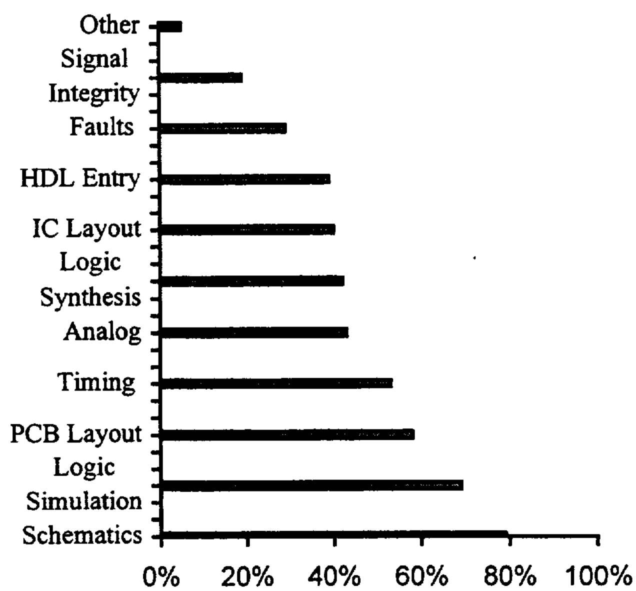

Figure 2.- Percentage Use of EDA Tools for Various Design Functions

Data from the same survey (see Figure 3) indicate that schematic entry is the most time-consuming task. While HDL entry and logic synthesis combined required only 10% of the design cycle, schematic entry requires 23%. This implies that HDL-based design implementations are more efficient than schematic entry approaches.

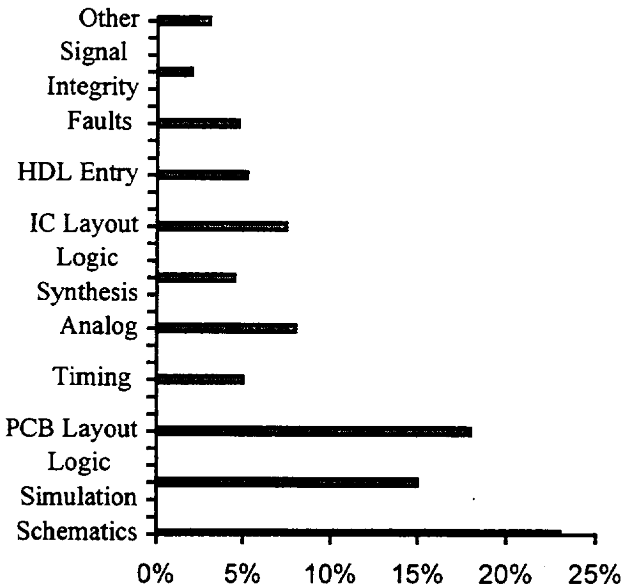

Figure 3.- Percentage of Total Design Time Used for Each Process

As electronic equipment becomes more complex, the capital and technical requirements of electronics manufacturing increase. As a result, many original equipment manufacturers are focusing on product development and using contractors for manufacturing [14]. The Institute for Interconnecting and Packaging of Electronic Circuits (IPC) forecasts that contract manufacturing will grow 20% annually through the year 2000. It is anticipated that by 1997, about 30% of all expenditures for PCB assembly will go to contract manufacturers. To decide whether to create manufacturing capability in-house or outsource, a number of business and technical issues must be assessed to ensure that the allocation of assets best matches the goals established for the organization. The financial ability to invest in manufacturing and the anticipated returns on investment are two major factors that should be considered.

DESIGN AND MANUFACTURING CAPABILITIES AT JSC

To assess the current JSC electronic design and manufacturing procedures and capabilities, I interviewed designers working on different projects in EM, EV, and ER. All the individuals I met were very helpful and exhibited a high level of dedication and professionalism. It was obvious however, that there are some weaknesses in the design capabilities and procedures. The following is a list of observations:

- There is lack of communication and coordination between different design groups.
- There are no standard manufacturing procedures.

- There is no standard software package (Software used include OrCAD, AutoCAD, VIEWlogic, Protel, CADSTAR).
- There are no electrical or mechanical simulation capabilities of complete systems -- Software is used mainly for schematic entry.
- There is duplication of work.
- The majority of individuals support the consolidation of the electronic design functions.
- The majority of individuals prefer in-house PCB rapid prototyping capabilities.
- Some individuals prefer in-house electronic manufacturing capabilities.

CONCLUSION AND RECOMMENDATIONS

The use of EDA tools based on concurrent engineering methodologies that support software-hardware co-design, virtual prototyping, and rapid prototyping is essential for a successful electronics design and manufacturing operation. To improve the current design and manufacturing functions at JSC, the following actions should be implemented:

- Form an overseeing committee that coordinates efforts regarding planning, training, software, hardware, etc. The committee must be derived from all major design groups at JSC to guarantee competent planning and effective communication.
- Acquire EDA tools that offer simultaneous access to all design teams (electrical, mechanical, manufacturing, etc.) and have the following capabilities: Schematic capture, HDL, electrical and mechanical simulations, PCB layout and simulation.
- Establish an EDA support center responsible for processes/procedures, training, technical support, integration of design tools, network administration, library development, equipment upgrading, licenses, etc.
- Consolidate the electronic manufacturing operations -- All orders are submitted to a centralized facility.
- Provide proper training for all technical personnel -- This is very crucial for a smooth and successful transition to the new environment.
- Maintain PCB rapid prototyping capabilities -- Communicate information to all customers and provide quality products.
- Postpone the decision regarding establishing in-house manufacturing capabilities until the electronic design functions are consolidated

The transition from the current structure to an integrated design environment can be completed within two years. This aggressive schedule assumes the support and commitment of everyone involved in the process. Acquiring EDA tools, developing procedures, and providing training may be carried out in five phases as follows:

I. Pre-Planning (1 month)

- Identify individuals who should be involved in the planning phase -- Project managers, design engineers, software specialists, etc.

II. Planning (4 months)

- Identify JSC design and manufacturing needs -- Survey designers, managers, technicians, and other appropriate technical personnel.
- Specify required design capabilities (software and hardware).
- Select software and hardware that satisfy the required design capabilities.
- Order hardware and software.
- Develop some design procedures based on concurrent design methodologies.
- Identify a pilot project and select the first group of individuals for training.

III. Equipment Procurement and Installation (1 month)

IV. Initial Training (3 months)

- Provide proper training to a group of 12 individuals including those who will constitute the support group.

V. Pilot Project (6 to 12 months)

- Implement design procedures and processes.
- Develop library.
- Refine processes and procedures.

VI. Full Conversion to the New Environment (12 months -- Start 3 months after pilot project begins) -- 40 to 50 people

- Provide proper training to groups of eight to ten designers at a time.
- Provide support at all levels in the design process.
- Continue developing library and revising processes and procedures.

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